



ISSN: 0975-766X  
CODEN: IJPTFI  
Research Article

Available Online through  
www.ijptonline.com

**CONCERNING THE ROLE OF MINERAL ADDITIVES IN COMPOSITE BINDER CONTENT**  
**Yuriy Mikhaylovich Bazhenov, Liliya Hasanovna Zagorodnjuk, Valery Stanislavovich Lesovik, Irina Vladimirovna Yerofeyeva, Natalia Vasilyevna Chernysheva, Dmitriy Alekseevich Sumskoy**

National Research University Moscow State University of Civil Engineering

Russia, 129337, Moscow, Yaroslavskoye Shosse, 26

Belgorod State Technological University named after V.G.Shoukhov

Russia, 308012, Belgorod, Kostyukov str., 46.

Belgorod State Technological University named after V.G.Shoukhov

Russia, 308012, Belgorod, Kostyukov str., 46.

Aleksandr Anatolevich Volodchenko Belgorod State Technological University named after V.G.Shoukhov

Russia, 308012, Belgorod, Kostyukov str., 46.

Mordvinian State University Named After N.P. Ogarev, Saransk.

Belgorod State Technological University named after V.G. Shoukhov

Russia, 308012, Belgorod, Kostyukov str., 46.

Belgorod State Technological University named after V.G.Shoukhov

Russia, 308012, Belgorod, Kostyukov str., 46.

Received on: 15.10.2016

Accepted on: 12.11.2016

**Abstract.**

One of the ways concerning cement production increase is the expansion of active mineral additives application from local natural and man-made material resources (domain granulated slag, ash and the slag of thermal power plants, coal beneficiation products and other materials) as raw material by increasing the production of portland cement with mineral additives, and other blended cements.

If builders will increase the demand for composite binders and other special types of cement, and our industry with science is capable to produce more than 80 types of cement, then the owners will stop to reduce the capacity of their business due to range changes and other factors. Of course, that along with the work on the construction of new and the improvement of existing facilities, cement plants will need to improve the range of produced cement on the agreement with builders, so that they make better use of its properties on the objects constructed by them. Thus, nowadays there is the issue of binder assortment optimization, the increase of composite binder share by involving the natural secondary materials of various origins into production.

**Introduction.** Cement industry is one of the main building material industries, where the man-made products are used as much as possible. The waste of such chemical industries as alumina-silicate (TES ash and coal waste use) is widely used as raw materials. Most often they use the rocks of mining and processing plants for cement production.

The know the use of iron ore tailings, electric thermal phosphorus slag as raw materials, but most of all domain granulated slag as an active mineral additive. A complex use of raw materials and industrial products can increase the production of many kinds of products by 25-30% and reduce its cost by 2-4 times. The disposal issue of large waste is international one. In USA technological the volume of technological product utilization exceeds 20%, 62% in France, and 76.5% in Germany. A similar pattern in Bulgaria and Poland. Thus, further development of concrete and reinforced concrete technology within "sustainable development" concept is related to composite cement use the material composition of which may have fine fillers, including the fillers of man-made origin [1-5].

The development of this trend was accelerated by the introduction of the new European standard EN 197-1, which standardized 27 different types of cement for general construction purposes. In accordance with EN 197-1, together with the clinker as the main constituents of cement granulated furnace slag, pozzolans, fly ash, burnt shale and silicate dust can be used generated during the production of silicon and ferrosilicon alloys.

### **Main part.**

Composite binders include the binders, obtained by the combining of air and hydraulic binders with active mineral additives of different genesis and slag during their co-grinding or after separate grinding.

At that the effect of adding filling additives is associated with the ability of cement "dilution" to some level that ensures an optimal balance between cement activity and concrete or mortar strength (trademark, class), and as a consequence, it results in cement savings. Technical requirements which should be observed by such additives are similar to raw materials from which active mineral supplements are produced: high dispersion rate - the specific surface of 200 ... 500 m<sup>2</sup>/kg, grain size is less than 0.1 mm; amorphous, glassy and partially crystallized structure; the provision of stable new formations during operation.

The special properties of slag cements include very slight expansion during heating and a high degree of resistance to an aggressive impact of natural and sea water, industrial waste waters.

The workability of slag cements is the same as for portland cement; heat release rate and the total heat release decreases during an early age. When cement properties are compared it is necessary to consider the amount of slag, the distribution of clinker and slag particles by sizes and the fact that slags are distinguished by reactivity. The introduction of a small amount of slag increases the strength, especially during early age. Slag reacts with water much more slowly than Portland cement. Thus the strength increase is a slow one. At an equal 2-day strength the

*Yuriy Mikhaylovich Bazhenov\* et al. /International Journal of Pharmacy & Technology*  
replacement of Portland cement by the cement containing 65% of slag can reduce the compressive strength almost by half in 2 days, but increase it by 12% during 91-day curing.

The use of high-quality ash improves the workability of a mixture, increases concrete compression strength, enhances the water resistance during the later stages of hardening and durability, reduces shrinkage and increases cement savings. All active mineral additives of pozzolan impact absorb calcium ions, which are released during the hydrolysis of basic calcium silicate with the development of additional hydration products.

The main feature of the pozzolanic activity is thermodynamic instability of glassy or amorphous components, as well as the chemical composition of pozzolans. Both natural and artificial pozzolans have a pronounced acidic character due to a high content of  $\text{SiO}_2 + \text{Al}_2\text{O}_3$ .

A detailed analysis of the pozzolanic reaction mechanism is presented in [1]. According to the author the main features of the pozzolanic reaction are the following ones: lower water cut of pozzolanic reaction products compared with the hydration products of ordinary portland cements; pozzolan aluminosilicate glass is hydrated slowly with the development of  $\text{S}_4\text{AH}_{(13-19)}$  or calcium carboaluminate at an initial stage with a further transition in hydrogarnet, aluminum hydroxide or gibbsite; due to the low concentration of  $\text{Ca}(\text{OH})_2$  in the liquid phase gypsum is developed into bisulfate during the first period or into ettringite during later periods; there is a linear correlation in a rock between pozzolan activity on lime absorption from a saturated solution and the degree of pozzolanic reaction; the content of  $\text{Ca}(\text{OH})_2$  in composite cement stone passes through the maximum sooner the more additive is introduced into it, and the higher its pozzolanic activity.

Pozzolan reaction products with calcium oxide include [2]: calcium hydrosilicate CSH (I) in the form of a gel with a low degree of crystallinity, but always located within the characteristics of tobermorite; hexagonal calcium hydroaluminate, and may be  $\text{C}_4\text{AH}_{13}$ . In special circumstances they found gidrogelenit  $\text{C}_2\text{ASH}_8$ ; ettringite ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}$ ) and bisulfate ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{CaSO}_4 \cdot 12\text{H}_2\text{O}$ ).

In [3] they indicate that the hydration products of slag and pozzolans are similar in composition. Vagier and Karl-Zhibeg [4] noted that a saturated solution of lime in the early period (15-20 days) experiences the dissolution of sulphates and the lime content is reduced by adsorption with the development of ettringite and a track. During the next period the content of calcium oxide hydrate and sulphate oxide increases considerably in a solution due to a slow silica dissolution process with the development of tobermorite at the expense of ettringite and gypsum development.

The author of the work [1] highlights the elementary acts of pozzolanic reaction:

1) dissociation of water;

2) The adsorption of hydroxyls on cationic centers of pozzolanic glass surface with a gradual withdrawal of cations in a solution and the substitution in surface oxygen coordination polyhedrons around  $\text{Si}^{+4}$  and  $\text{Al}^{+3}$  oxygen atoms into hydroxyls (subject to the regulations 3 and 4);

3) the penetration of  $\text{H}^+$  in the dislocation channels and other surface defects with the following complex development "proton - glass lattice defect";

4) interaction of the specified complexes with the oxygen atoms of pozzolan lattice to develop "structural hydroxyls" fixed on IR spectra;

5) the obtaining of an excess negative charge by a pozzolan surface, due to the release of cations in a solution and the accumulation of structural and surface hydroxyls;

6) the adsorption of calcium cations and alkali metals from the porous liquid by pozzolan surface to offset this charge, passing in a chemisorption and accompanied by the emergence of  $\zeta$ -potential;

7) the release of chemisorption interaction of silica and aluminum-hydroxy anions in a product solution with specified cations and the development of a separate phase from a solution - the first product pozzolanic reaction. These new formations are potassium-sodium ones. However, their solubility in a porous fluid is higher than the similar calcium new formations - the second product of pozzolanic reaction, gradually displacing the first one on a pozzolan surface and in a solution which is a more stable product of pozzolanic reaction;

8) the formation of an additive pozzolanic particles on a semipermeable film from original and secondary hydration products;

9) the continued hydration process under a film and the release alkali ions into solution, calcium,  $\text{SiO}_4^{-4}$  and  $\text{AlO}_4^{-5}$  tetrahedra that gives rise to an osmotic pressure appearance in a contact zone;

10) the suction of water under a film at the influence of osmotic pressure, the destruction of films, the occurrence of steric pores with the thickness of 1-2 microns, separating an additive grain from a cement paste;

11) a gradual overgrowing of a steric pore with new formation crystals formed as the result of pozzolanic reaction front promotion inside an additive grain;

12) the development after a complete overgrowing of a pore structure resembling Jung microconcrete, however, with a fundamental difference that the role of a micro filler in it is played not clinker residual grain but the relics of supplement grains.

Thus, the analysis of individual stages of a pozzolanic reaction allows to conclude that its speed is largely determined by the total surface of additive particles, as well as by mechanic-chemical activation occurring during cement grinding.

The author gives a special role [5] to the transition zone between a cement stone and pozzolana particles with the thickness of 5-7 microns. The number of such contacts makes 15 - 20% of a cement stone total volume.

It is believed that the pozzolanic reaction of ash in a construction mortar begins after a certain time after a mixture preparation, from 14 to 40 days approximately [6]. Watt and Gorne divided ash into fractions by different activities and confirmed that the glassy phase is the most active part of the material [7].

During the study of the interaction with hydraulic additives, the following types of hydraulic additive activation are specified: sulfate activation and alkali activation [8]. Slag react very poorly with water without activation. According to F. Schroeder [9] during the consideration of active slag interaction processes with water it is necessary to distinguish hydration that occurs mainly in a saturated  $\text{CaSO}_4$  solution (supersulphate binders) and hydration, which is entirely completed in a saturated or nearly saturated solution, a solution of  $\text{Ca(OH)}_2$  (slag portland binders). Ettringite is developed during the sulfate activation of slag by anhydrite in sulfate cements, CSH type phases, actively involved in strength property development (pH less than 12). Alkaline activation takes place at pH greater than 12, thus tobermorite, ettringite phases and hexagonal calcium hydroaluminates are developed. The mixtures containing a lot of  $\text{Al}_2\text{O}_3$ , also have gehlenite hydrates and hydrogarnet in small quantities.

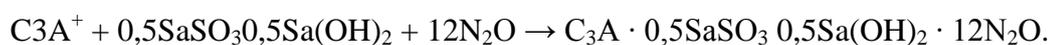
V.I. Satarin [10] explains the mechanism of slag glass hydration, determined by their structure as follows. Negatively charged hydroxyl ions penetrate into glass, at that an electrostatic equilibrium of a system is disturbed, which is possible only in the presence of coordinated uncompensated anionic groups, and slag glass begins to break down. Hydrated phases replace gradually the initial grains of glass by exchange reactions between hydrogen and hydroxyl ions in a solution and the alkali soil slag glass. The structure of hydrated product has a gel like structure. Satarin suggested that the slag cement and Portland cement develop amorphous non-stoichiometric hydrates with high surface energy in the process of curing. The crystalline phases are presented by: 1)  $\text{C}_3(\text{A},\text{F})\cdot 3(\text{CaSO}_4, \text{Ca(OH)})_{\text{aq}}$  - Aft-phase; 2)  $\text{C}_3(\text{A}, \text{F})\cdot(\text{CaSO}_4, \text{Ca(OH)}_2, \text{CaCO}_3)$ ; 3)  $\text{Ca(OH)}_2$ , in some cases hydrate gehlenite  $\text{C}_2\text{ASH}_8$ , hydrogarnet  $\text{C}_3(\text{A}, \text{F})\cdot 3(\text{S}, \text{H}_2)$  and dicalcium hydroaluminate  $\text{S}_2\text{AN}_8$  are found with a high slag content in  $\text{MgO}$ , hydrotalcite-like hydrocarboaluminates  $\text{Mg}_6\text{Al}_2\text{CO}_3(\text{OH})_{16}4\text{H}_2\text{O}$  are found.

They often use fine carbonate rocks as inert additives. It was found [11-16] that limestone is not an inert diluent and during cement hydration it reacts with tricalcium aluminate to form calcium carboaluminates. At the same time there is such a formation as high carbonate form of carboaluminate  $C_3A \cdot 3CaCO_3 \cdot 32N_2O$  and low carbonate  $C_3A \cdot CaCO_3 \cdot 12H_2O$ . According to physical properties these variations are close respectively to highly sulphate (ettringite) and monosulphate form of calcium sulfoaluminates. The addition of limestone in cement is similar to the addition of gypsum and may have a regulating effect on cement setting and the rate of  $C_3A$  and  $C_3S$  hydration reactions. The best effect from the use of limestone in cement is achieved with a higher content of  $C_3A$  in a clinker. The binders with limestone, obtained on the basis of clinkers with an increased content of  $C_3A$ , and such binders as is known behave worse during hydrothermal treatment. Primarily they should be used in concretes, curing in normal conditions.

Timashev's works and the works of other authors [13-15] noted that the use of carbonate additives in cement composition of the carbonate cement helps to reduce water demand, peelability and the water separation of concrete mixes, the increase of their water-holding capacity, plasticity, density and uniformity, shrinkage, water absorption and thermal emission of concrete reduction, and also improves their weather resistance, water, frost, acid resistance and the resistance to an aggressive impact of sea water.

Using the method of Gibbs potential minimization they studied the regularities of phase formation during the hydration of  $3CaO \cdot Al_2O_3 - CaSO_4 \cdot 2H_2O - CaCO_3$  system [16]. It was found that if the content of  $CaCO_3$  in a system makes up to 3.4 wt.%, the latter acts as an active component forming calcium hydrocarbon aluminates of different composition. With further increase of  $CaCO_3$  content it begins to act as an inert additive. The introduction of  $CaCO_3$  in a system leads to the stabilization of ettringite  $3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$  in a hardened cement composition [16].

The authors [15] studied the combined effect of blast furnace slag and limestone on cement properties. It was shown that the effectiveness of slag and limestone mutual influence in a composite cement content is in the higher amount of calcium carbon aluminum hydrates generated in the system with slag and limestone, as compared with a system without slag. Slag accelerates  $C_3S$ ,  $C_3A$ , and especially  $C_4AF$  hydration. The process proceeds according to the following reaction:



The reaction product fills the pores and increases the compressive force.

Thus, carbonate rocks in cement composition play a positive role and give them special properties.

The results of research showed that particulate composition is of great importance in composite binders. The process of a clinker and gypsum grinding with active mineral additives is a key one in respect of influence on a material and the most energy-intensive one. During grinding the physical-chemical activation of components takes place defining the properties of a binder. Companies strive to ensure adequate fineness of produced cement, a high activity (grade) and simultaneously get an optimal performance of the cement mill park [17]. According to [18], at an average grade of 415 and 11-12% of residue on the sieve 008 42 kW·h of energy and 1 kg of steel per 1 ton of cement are consumed. In [19-21] they studied the grindability of composite binders depending on a filler type and content in the form of fly ash. The results showed that fly ash and sand have a positive impact on the grindability of binders and blast furnace and phosphorus slags make a negative impact. Thus, with the addition of fly ash to a fineness up to 30% a binding grinding finesse after makes 370 m<sup>2</sup>/kg after 2 hours and with the addition of 50, 70 and 85% it reaches 460, 540 and 550 m<sup>2</sup>/kg respectively.

A specific binding surface with phosphoric slag addition under determined conditions did not exceed 420 m<sup>2</sup>/kg and with the addition of blast-furnace slag - 350 m<sup>2</sup>/kg [20]. The more slag in the composition of binders, the worse they are ground, at that more time is necessary in order to achieve the required fineness of binders with the addition of slags. Thus, the specific surface of a ground binder reaches 450 m<sup>2</sup>/kg with the addition of sand after 8 hours, then a specific surface of binders makes 400 m<sup>2</sup>/kg only after 10-12 hours as a phosphoric slag filler; with the addition of blast furnace slag during the same period of grinding the specific surface of binding is lower - 330-350 m<sup>2</sup>/kg.

The work [21] noted that the composite binding regrinding together with a filler enhances the concentration of active centers like Bronsted acid sites and Lewis basic centers significantly on the surface thereof. Besides, the increase of grinding fineness causes mechanic-chemical processes in binders, thus the surface of the particles and their components becomes an amorphous one.

The practice of composite binders application in Russia is poor. In European countries, composite binders are the most simple and affordable way to save fuel in the cement industry, as well as utilization of mineral waste from other economic sectors. In this regard the solution to these issues in EU countries is of interest [21].

Berlin Research Institute of the German cement industry (further referred to as the RI of cements) offered the recommendations on the use of composite binders according to the study results [21]. The purpose of the Research Institute is the cement material composition optimization for their unlimited use in all areas of concrete works. The

key point in the studies is the interaction of cement and additives, regulating the technological properties of cement compounds.

In 2000, the structure of ash and slag waste use in the EU countries was characterized by the following data in the percentage to the total volume of waste: 1) fly ash as an additive to concrete - 33%, the additive to cement - 11%, cement raw materials - 23%, concrete blocks - 6%, in road construction - 22%; 2) fuel slag - concrete blocks - 46%, cement - 7%, lightweight filler - 2%; 3) ash and slag mixture - road construction - 52%, instead of fine sand - 31%, in mortars and concretes - 14%. Fly ash is the main type of ash and slag waste used in the cement industry of foreign countries. The possibility of its use as an additive to a binder is normalized by the standards of all major industrialized countries. It is ASTM C 618 in the USA [22], JISR 5212 in Japan, and EN 197-1 in the European Union. A great attention to the use of fly ash as an additive in the production of a binder is paid in China, which accounts for about half the world's cement production. According to the new Chinese standard GB 175-2007 [23], the input of fly ash in the amount up to 20% from the weight of cement is allowed in an ordinary Portland cement, and also a special ash-Portland cement is provisioned with fly ash content of 20 - 40%.

In scientific research, conducted by the Research Institute of cements concerning concrete durability produced of mixed cements, the reaction of alkali silica was interesting. During studies carried out on a small section of a roadway concrete pavement after 6-10 years of operation the damage were found resulting from such a reaction. During the reaction of silicic acid with alkali the granulometric composition sensitive to alkali react in a concrete with porous solution alkali and with alkali silicate development, which tends to absorb water. The associated increase in volume results in expanding pressures. This can damage a concrete structure and reduce its durability. The scientific results of cement PNI on the reduction of alkali reaction harmful effects with silicic acid were included in new German standards within the field of concrete. This happened before the transition from the old generation of standards to a new one, while the use of DINEN 206-1 [24] and DIN 1045-2 [25] was allowed for the construction of new facilities. The amount of shipped cement in Germany helps to estimate the future potential of new cements according to its practical application. The following categories were compared: high-rise construction, engineering construction, and the construction of underground structures, traffic areas, settlements, roads, and other areas of application. It turned out that about 50% of cements, produced at Germany plants is intended for transport concrete production for interior and exterior building components, conventional overground structures, i.e. for residential and industrial construction.

German binders with the strength class of 32.5, which include several components, comply with all essential requirements of monolithic concrete, whether it is the transport concrete or the concrete for construction sites. All these binders have enough ability to gain strength quickly. The concretes which contain these binders have a sufficient protection against steel corrosion under the action of carbonation and chloride impact.

Mainly all binders are suitable according to EN 197-1 for the manufacture of concrete according to DIN EN 206-1 [24] and DIN 1045-2 [25] standards. Taking into account the durability of concretes, produced with these cements, the RSI of cements points out to the dependence on the field of their use and on the difference of cement types. For this purpose, the concrete standards require to set various rules for their application depending upon a class strength to which a construction detail corresponds. RSI of cements put forward a number of limitations to the use of CEM II cements (they were not used in Germany until now), mainly for Portland cements with limestone content up to 35 wt.% (CEM II/B-LL), as well as for composite cements with blast furnace slag and limestone content up to 35 wt.% (CEM II/BM(S-LL)). The restrictions apply mainly frost resistant and chloride containing building parts. If such binders should be used in the areas in which concrete standard has no tolerance, then it requires the construction supervision approval. This applies to new cements CEM II-M, which were developed by the German cement producers. With the increase of these cements practical value, relying on the database developed during the research process, the need of these tolerances is not necessary, although the rules of their use must be changed. The SRI of cements carried out the works on database expansion for concretes using new composite Portland cements. For this purpose they calculated the parameters of Portland cement strength containing up to 35 wt.% of lime (CEM II/B-LL) and composite binders containing granulated blast furnace slag (35 wt.%) and limestone (CEM II/BM(S-LL)). The subject of further research were the portland binders with 35 wt.% content of fly ash, which contain a large amount of silica and the composite binders CEM II-M (V-LL) and CEM II-M (SV) of different composition. Our researchers [26-35] proved the high efficiency of mineral additive use in the manufacture of composite binders, building materials and the products for various purposes.

## **Summary**

Further development of concrete and reinforced concrete technology is associated with the use of composite binders under the concept of "sustainable development", the material composition of which makes it possible to use fine disperse additives of different genesis. One of the ways for cement production increase is the expansion of active mineral additives application as local natural and man-made material resources (furnace granulated slags, ashes and

thermal power plant slags, coal enrichment products and other materials) by portland cement production increase with mineral additives, and other composite binders.

## **Conclusions**

The technical effect of additive fillers introduction is associated with the ability of a binder "dilution" to the level ensuring the obtaining of an optimal balance between a binder activity and concrete or mortar strength (brand, class) and as the result, the savings of a binder. A new interstate standard GOST 31108-200, provides the expansion of cement production range, including a wide range of natural and technogenic supplements. The portland binders containing up to 35 wt.% of active mineral additives, fillers in the form of from fine lime up to 20 wt.%, additive compositions up to 80 wt.% comprising granulated blast furnace slag, fly ash, natural pozzolans, burnt clays, micro silica and limestone are standardized. The content of blast-furnace slag and the pozzolans in slag and pozzolanic cements changed. The content of slag in slag portland cements reaches 35 - 65 wt.% and pozzolanic cements allowed the use of composition from man-made and natural pozzolanic additives, the content of which makes 21 - 35 wt.%. There is no unified classification approved in regulatory documents in Russia concerning the classification of natural and man-made supplements. The classification proposed by RILEM, allows to evaluate man-made materials in terms of their impact on cement systems, so it is more objective than a usual classification of mineral supplements by their origin. The chemical and mineralogical compositions of man-made products are very wide, which results in their chemical or hydraulic activity during the process of composite binder hydration.

The mechanisms of pozzolan and hydraulic activity of additives are different, so there are no common criteria and the methods for an additive efficiency determination in the composition of composite binders. One of the factors that affects the formation of a cement stone structure made of composite binders with a particular pore and void system can be the packaging of cement grains during their contact with water, as this affects the density of a developed cement stone and its homogeneity. Different particulate content of a composition binder is determined by the type and amount of an additive, as well as its grindability.

It is necessary to develop the guidelines on the rational application areas for composite binders with regard to their material composition, as well as depending on the strength class and application conditions.

## **Acknowledgements**

Article is prepared within realization of a basic unit state. tasks of the Ministry of Education and Science of the Russian Federation No. 1978 NIR as of 31.01.2014.

## References

1. Entin, Z.B., 1993. Chemistry and technology of finely ground multicomponent cements: Abstract from the thesis of techn. science Doctor: 05.17.05. RHTU named after D.I. Mendeleev, 49 p.
2. Massatsta, F., 1976. Chemistry of pozzolanic additions and blended cements. The Sixth International Congress on Cement Chemistry, 3: 209-221.
3. Ducreux, R., 1962. The effect of the Pozzolanic Behavior of Fly Ashes as Ad to Cement. Silicated Ind., 27 (11):517-529.
4. Vaquier, A., and A. Carles-Gibergues, 1970. Role of Sulfates in the Pozzolanic Properties of a Fly Ash from Steam Power Plant. Rev. Mater. Constr. Trav. Publ., (662): 331-337.
5. Morgan, W.T., and J.L. Gilliland, 1960. Summary of Methods for Determining Pozzolanic Activity. Symposium on use of Pozzolanic Materials in Mortars of Concretes, ASTM spec Tech., Publ., 99: 109.
6. Sersale R., 1971. Mechanism and Reaction Products of Lime with Pozzlanas And Blast Furnace Slags. 20, New Ser., pp. 5-13.
7. Watt, J.D. and D.J. Thorne, 1965. The Composition and Pozzoanic Properties of Pulverized Fuel. J. Appl. Chem., 15: 585-604.
8. Starin, V.I., 1976. Slag portland cement. The Sixth International Congress on Cement Chemistry, 3: 45 - 56.
9. Schroeder, F., 1973. Slags and slag cements. The Fifth International Congress of cement chemistry. pp. 422-437.
10. Satarin, V.I., Ya.M. Sirkin and M.B. Frenkel, 1970. Fast setting slag portland cement, pp.: 152 p.
11. Smolczyk, H.G., 1963. "Zement-Kalk-Gips", 18: 238-246.
12. Nurse R.W. and In H. W. F. Taylors, 1964. The Chemistry of Cements, V. 2, Asad. Press, London, N.Y.,pp.37-67.
13. Suzuev, N.A., T.M. Khudyakova and S.A. Nekipelov, 2009. Some concrete properties produced from carbonate Portland cement. Construction materials. 9: 20-22.
14. Timashev V.V. and V.M. Kolbasov, 1981. Properties of cements with carbonate supplements. Cement, 10: 10-12.
15. Hoshino, S., Kazuo Yamada and Hiroshi Hirao, 2006. XRD/Rietveld Analysis of the Hydration and Strength Development of Slag and Limestone. Blended Cement Journal of Advanced Concrete Technology 4(3): 357-367.
16. Sivkov, S.P. 2008. Thermodynamic analysis of the phase formation during carbonate containing cements solidification. Cement and its applications, 4: 112-115.

17. Entin, Z.B. and L.S. Nefedova, 2008. About dispersion and granulometric sizes of Russian and foreign cement. Cement and its applications, 2: 86-88.
18. Kolbasov, V.M., I.I. Leonov and L.M. Sulimenko, 1987. The technology of binding materials, pp: 431.
19. Tolochkova, M.G., 1969. The use of fly ash as a supplement. Cement, 9: 17-19
20. Kuznetsova, T.V. and G.P. Grigoriev, 1972. Fly ash as an additive for cement. Cement, 4: 14-16.
21. Wilhelm Geiger GmbH and Co. Tätigkeitsbericht, -2005. Verein Deutscher Zementwerke e. V. Forschungsinstitut der Zementindustrie. Dusseldorf. p. 99-127.
22. ASTM C618-01 – Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture.
23. GB 175-1999. Portland Cement.
24. DIN EN 206-1 Concrete, reinforced and prestressed concrete structures.
25. DIN 1045-2. Tragwerke aus Beton, Stahlbeton und Spannbeton – Teil 2: Beton; Festlegung, Eigenschaften, Herstellung und Konformität.
26. Zagorodnuk, L.H., V.S. Lesovik, A.V. Shkarin, Belikov D.A. and A.A. Kuprina, 2013. Creating Effective Insulation Solutions, Taking into Account the Law of Affinity Structures in Construction Materials. World Applied Sciences Journal 24 (11): 1496-1502.
27. Lesovik, V. and I.L. Chulkova, 2011. Managing a structure formation in construction composite. Publishing SibADI, pp: 462.
28. Lesovik, V.S.. Geonics (geomimetics), 2014. Examples of application in building materials science. Belgorod, pp: 206.
29. Lesovik, V.S, 2015. Technogeneous metasomatism in building materials science. In International collection of proceedings «4C - Building materials: composition, structure, properties» Novosibirsk, pp.: 26-30.
30. Lesovik, V.S., L.H. Zagorodnuk, M.M. Tolmacheva, A.A. Smolikov, A.Y. Shekina and M.H.I. Shakarna, 2014. Structure-formation of contact layers of composite materials. Life Science Journal, 11(12s): 948-953.
31. Kuprina, A.A., V. S. Lesovik, L.H. Zagorodnyk and M.Y. Elistratkin, 2014. Anisotropy of Materials Properties of Natural and Man-Triggered Origin. Research Journal of Applied Sciences, 9: 816-819.
32. Lesovik, V.S., I.L. Chulkova, L.H. Zagorodnjuk, A.A. Volodchenko and D.Y. Popov, 2014. The Role of the Law of Affinity Structures in the Construction Material Science by Performance of the Restoration Works. Research journal of applied sciences, 9(12): 1100-1105.

33. Volodchenko A.A., V.S. Lesovik, L.H. Zagorodnjuk, A.N. Volodchenko and A.A. Kuprina, 2015. The control of building composite structure formation through the use of multifunctional modifiers. *Research journal of applied sciences* 10(12): 931-936.
34. Volodchenko A.A., V.S. Lesovik, A.N. Volodchenko and L.H. Zagorodnjuk, 2015. Improving The Efficiency Of Wall Materials For «Green» Building Through. The Use Of Aluminosilicate Raw Materials. *International Journal of Applied Engineering Research*, 10 (24): 45142-45149.
35. Volodchenko A.A., V.S. Lesovik, L.H. Zagorodnjuk, A.N. Volodchenko and E.O. Prasolova, 2015. Influence Of The Inorganic Modifier Structure On Structural Composite Properties. *International Journal of Applied Engineering Research*,. 10 (19): 40617-40622.